# Intelligent Tutoring System for Assessment of Usage of Computer Aided Designing Systems

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**Abstract.** Computer aided design (CAD) training and its aspects are described and analyzed in the paper. It looks at a traditional and technology-supported learning process aimed at analyses of teaching CAD and provision of knowledge assessment, as well as identification of problems in the CAD system training process. It was concluded that technology-supported learning process would contribute to solving these problems. An analysis allows set requirements for the intellectual tutoring system in the CAD system training. As the main problem in the use of CAD systems and in the assessment of learner's results, there is an identifiable lack of information about the learner's actions during execution of their tasks. Since an instructor issues an assignment, a student executes it and submits the result then the instructor acquires information about the results of the learner's work, but not the process itself. It is difficult (even impossible) for him to analyze the efficiency of the work performed – compliance of the tools/ functions used for the execution of the task, the sequence of the process, and its practicability. Based on the study carried out, approaches for assessment of the use of computer-assisted design systems were offered for implementation within the framework of the study. The system created allows solving assessment problems of the use of CAD systems: an expert is being informed about activities of the learner during the execution of the tasks, the process of task completion.

**Keywords:** Computer aided design, intelligent tutoring system, knowledge assessment.

## 1 Introduction

Modern computer-aided design software (CAD systems) allow one to avoid manual routine work, increase accuracy, productivity and organize the flow of information. Computer systems are designed for computerized performance of every process and integration of all processes in shared flows, the organization of logistics and life cycle of the product as well as mobility of work tasks. Although computer systems are facilitating development of the product considerably, essential remain the knowledge and skills of users of the system. Although the integrated tools allow for automatization of different stages of design and production planning, insufficient designer knowledge of product design processes, design parameters, material features and other aspects will lead to poor, non-compliant or non-feasible projects. In addition to such complex knowledge, learning of the CAD system use is an additional aspect of knowledge required by specialist training.

Computer Aided Design, along with Computer Aided Manufacturing, emerged in the 1950s [1]. A well-known term for Computer Aided Design and Computer Aided Manufacturing Systems is CAD/CAM. Currently, CAD/CAM systems are used in a variety of fields, which include design and manufacturing management processes (Geometric modelling, Machine vision, Flexible manufacturing systems). Using specialized computer software, a created technical drawing, a specialized set of parameters (procedure description) describe the computer-aided designing. Design engineering, technical drawing and drafting combine extensive knowledge of theory and practice. Creation of a design is a very complicated process in itself [2, 3]. Using computer-aided design contributes into designers' work productivity, humanization of working conditions, project quality improvement, communication speed, flexibility and the structuring and expansion of the production data repository. If the result of a computer-aided design (a project created in a CAD system) is immediately (without a design draft or printing) given for production (cutting, machining) of a product, it is called computer-aided manufacturing (CAM system software).

Designing in CAD/CAM systems shall be carried out according to the work task: the drawing resulting from the designing is different, depending on the characteristics and uses of the subject matter. Since it is not possible to provide for all possible drawings (and thus to formalize the task), the assessment of working with the computer-aided design systems includes the following important factors:

- sequence of activities,
- the logical reasoning of activities,
- time devoted to work,
- tools used.

## 2 Learning computer aided designing

Comprehensible that one of the main stages of the designing is drawing, from the sketch of the product to the technical drawing. The drawing comprises all design aspects of the product: the main dimensions are characterized by structure and base network, the specialties of the product design are characterized by contour lines, character lines and construction lines (the construction lines may not be distributed, depending on the scope and specificity of the design). The implementation of all these elements of the drawing items (point, line, square, circle, and other geometrical figures) in the computer system may vary according to nature of the system used. A general CAD system designed for a broad range of design tasks or a narrowly specialized system with integrated functions for specific production elements or blocks of a specific production area. Similarly, the drawings of all these objects may have an integrated (specialized) function/tool, or a number of graphic item drawing functions may be used (such as a base network, if it is a rectangle capable of being constructed with a rectangular tool and with four separate features). All these aspects highlight the complex knowledge structure that the system user needs to learn in addition to the knowledge on production, which, as already mentioned, may be specific in the form of a different production and design organization.

### 2.1 Learning circumstances

Gaining of new knowledge is undermined by the fact that different CAD systems are available on the market as well as for the performance of one specific field design work; a head of a production company can purchase different systems. This choice is based on economic considerations primarily –system price and service level, systems used by co-operation partners, convenience of data exchange, price of peripheral equipment, and suitability for specific production. This diversity of the market in CAD systems makes it difficult for highly-skilled workers to stream the market flow – knowledge in one system may not be sufficient to work with another system. In addition, training of existing system users (experts) should be regularly provided, taking into account the process of developing of permanent systems and placing of new versions on the market. Because of the license management process, the latter is binding to every company. Depending on the system vendor and vendor policies, licenses may be with a specified deadline after which the system stops working, or the older version system files are not recognized in the latest and vice versa [3]. There may be differences in use within the same system as the system is designed so that the maximum working area is dedicated directly to painting/drawing, while the deployment of functions/tools and commands in most systems is adaptable to the user's convenience (the function keys can be moved and placed in a convenient screen location).

No aspects facilitate the training exercise – the knowledge to be acquired is not only complex and different depending on the scope, but the traceability and transparency of the learning processes (CAD systems) are also difficult or even impossible to assess.

### 2.2 Training methods

While the training in computer-based design system use is most commonly carried out according to the traditional learning process [4, 5], in which a teacher provides knowledge in the form of lectures and exemplary demonstrations. The learner takes the new information and understands it and consolidates knowledge through practical tasks, given that CAD/CAM systems based on information technology are taught, most systems have integrated technology-backed learning tools. Online Help is part of the system that allows the learner to obtain information about operation of the system as a whole or for the design of a particular function or tool. Systems tend to be integrated with both help in which the user searches for information and help that can be obtained on a request for a given, time-active function/tool. Such assistance, when wisely used, allows one to choose an appropriate operating algorithm for solving their task.

If the knowledge provided by the teacher is purely theoretical, without real use, then the interest by trainees may be low-leveled and there may be no incentive to learn the computer aided design. By providing real examples of computer aided design (in addition, these example models may be both real and virtual), corresponding to age, education level and future profession of learners, the trainee is enabled to acquire knowledge on the CAD/CAM systems. If the trainees are convinced that sufficient knowledge of the use of computer aided design systems has been obtained, i.e., they have received sufficient feedback, they know that they can use their CAD knowledge in work, get better-paid job, their training motivation grows.

In addition to work skills (system usage skills), the accuracy and speed of creation of the graphic result is important when working with the creation of graphical files. For graphical tasks in the CAD/CAM system a certain sequence/order has been put in place, but the quality (accuracy, speed) of tasks performed is directly affected by the drawer's knowledge and skills in the use of the system. Examination of such projects shall include an assessment of the result and documentation, but for the knowledge examination on the CAD/CAM system no single approach has been developed, therefore, it is not possible to verify the sequence of actions performed its passage, the procedures and the process of development.

### 2.3 Knowledge gaining process

Knowledge in the use of the computer aided design systems shall be obtained from initial training when the knowledge provided by the teacher is taken over and used in the computer system [5]. A step-by-step approach is the most common way of learning the computer aided design systems –a teacher shows how every activity can be performed, and the trainee repeats it at their PC. Sometimes (very rarely) learning takes place remotely through the user guide or video training. An important step of learning is feedback: if the trainee has not understood the activities to be performed and is unable to perform a lesson task, the teacher answers questions, shows individually what actions are to be taken to continue and/or correct the execution of the task. In most cases, the rise in knowledge acquired at the start of training is very small –the trainee does not understand the nature of computer aided design, is confused about the use of system tools/functions and unable to perform the tasks of the lesson. It is therefore proposed, before developing a serious project, for the trainee to perform simple tasks for acquisition of graphic basic units, as drawing lines, parametric or non-parametric display of clusters, circles and other geometric figures. When the trainee has mastered the system usage principles, further training may occur with the rise in knowledge being very rapid. Linear, where the slope factor of the line graph depends on the capacity of the trainee, the time spent in the training and the quality of its use (see **Error! Reference source not found.**).

After the initial training, the use of the system is followed, during which knowledge is secured and, in carrying out realistic design tasks. This also require the use of knowledge of the object to be designed, covering the necessary parts of the drawing – the base network, lines, drawing lines, construction lines and other required project attributes. Knowledge is complemented by the practical use of the computer aided design system (the stage may be integrated in both the training process where the trainee performs study finals or specialized training courses within the study project as well as during the performance of sectoral practice tasks, i.e., while on studies or at workplace). At this stage, acquisition of new knowledge does not occur rapidly.

Further education (or further training) approaches the next stage of knowledge acquisition. If the designer has an interest in in-depth learning of the system, it is possible to acquire it at the level of the connoisseur in life-long learning courses or at higher levels of studies. This stage also comprises the training of experts whose working techniques in the CAD/CAM system need to be improved. Further training stages depend on the specific system – the frequency and complexity of updates, and these stages are repeated periodically.

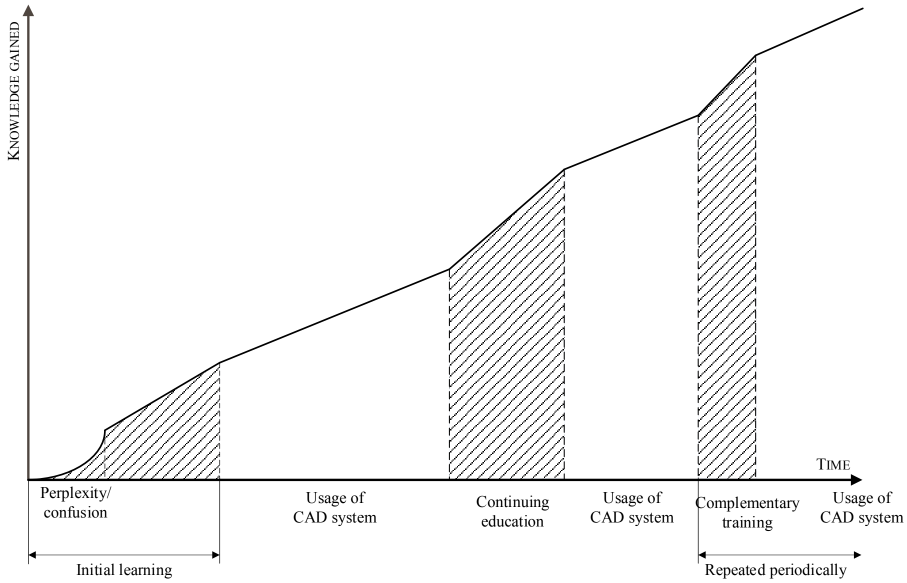


**Fig. 1.** The scheme of CAD/CAM learning process.

In a study on the preparation of students for the role of future engineers [6], a survey was conducted that found that only 8% of the students (after starting their careers) expressed satisfaction with computer-aided design courses, 18% felt that too much mathematics, computer science and mechanics were included in the training, while 74% of the respondents acknowledged that all of these aspects, as well as the system practical application should be included in the curriculum to a greater extent.

The result of teaching is traditionally evaluated according to the change in students' behaviour/actions after the training process. Analyzing the methods of computer-aided design training process for assessment of the outcomes, it is concluded that there are no opportunities to assess the process / execution of tasks, but only the result and the knowledge acquired by students. This highlights the need for a new approach.

Introducing an intellectual/computerized system into the training process, it is possible to achieve greater training effectiveness, provide learning which is not influenced by time (students learn when they choose) and place (students learn where they choose), and provide both feedback to students and information on students' activities and the time devoted to designing that would allow to make an appropriate assessment of the work performed.

## 3 Intelligent tutoring system for knowledge assesment

Structure of the intelligent tutoring system (ITS) shall be based on the basic components of the traditional training process: teacher, trainee and training content. These components define the basic elements of the ITS architecture, i.e., modules [7, 8]. The modules are interrelated; number of these modules may be supplemented depending on the purpose and tasks, problems and other aspects of the system. The system is composed of an expert module, a student (trainee) module, a training (learning content) module and a user interface. Individual functions shall be provided in each system component (module).

The student module is of an accumulating type - it accumulates information about the activities, success and test results performed by the student. The expert module, in its turn, contains information about training. This can be complemented and, in collaboration with the student module, bring changes to the learning content to approach the training module to resolving of the students' problems. The training module stores and reflects the learning content, and for acquisition of it, the module collaborates with the remaining ones. With the assistance of user interface, work with the training system is ongoing.

### 3.1 ITS architecture

To select an ITS creation platform, it is useful to know that the CAD/CAM systems currently available on the market are based on MS Windows platforms. In an analysis of the situation industry experts conclude that the systems that were built on other platforms during the initial computerized design development stage are built for MS Windows environment exclusively. This was so due to the need to migrate data between systems and collaborative companies: ensuring data compatibility between computer project systems is a complex task already. Most systems store data in similar formats; registry libraries are used simultaneously; in addition, because of business competition, the stored formats, even if they are with the same extension, are incompatible when using a different CAD/CAM system. For these reasons, CAD/CAM is provided only on the Windows platform.

Intelligent tutoring system based on intelligent agent technologies (see Fig. 2.) elaborated for assessing trainee’s performance within CAD/CAM system. It is therefore possible to assess the result of the work performed. Process analysis is an important aspect in order to reduce working capacity and therefore, resource capacity (time, human work and salary, total project costs) used during the execution of the particular work.

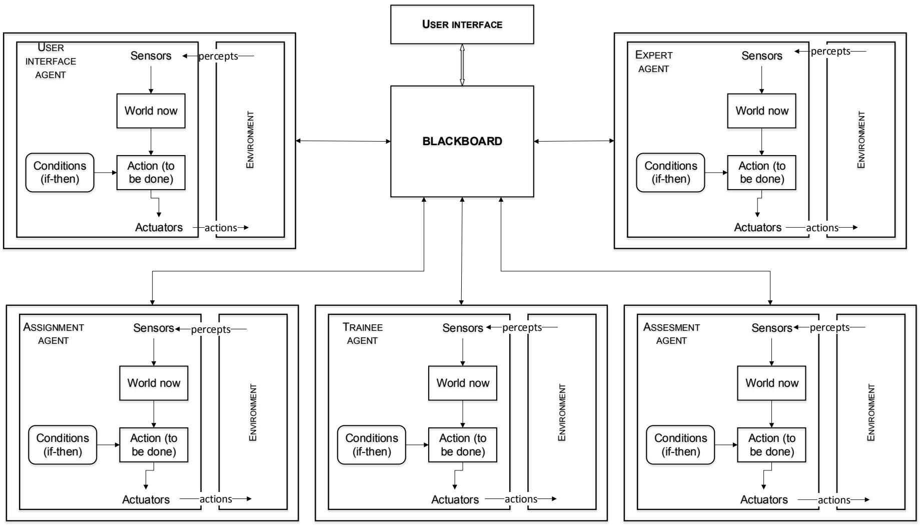


**Fig. 2.** The scheme of agent system.

By developing a system in which agents co-operate mutually by observing, analyzing, collecting information, communicating, and making diagnosis of the trainee's skills at CAD/CAM system (AutoCAD, Lectra, bCAD, Grafis, etc.), it is possible to track student activities (speed, accuracy, tools, coherence and sequence) and thus perform the diagnosis of the trainee's skills, and adapt tasks and additional learning material. The ITS architecture uses the classic modules – a student module, an expert module, and a training module supported by agents' activities. The following agent captures, through the interface agent, the activities of the trainee on the working surface, the transfer of function keys, the order of execution, time, the functions used, duration and frequency of the use, actions with the ITS keys. The system stores data in the database, and the agent transfers the information obtained to the knowledge assessment (evaluation) agent. Through the interface agent, the expert agent obtains information about the expert, their activities in the system, transfers tasks to the database, transfers information to the assignment and knowledge assessment (evaluation) agent. The assignment agent communicates with both the expert agent and the evaluation agent, assigns tasks according to the necessary test.

For implementation ITS, agents capable of cooperating are used: the common objective of integrated agents is the implementation of the training process and the facilitation and diagnosis of learning outcomes. The system design provides collaborative and communicative protocols (for physical transmission of messages and specifying the message syntax) which is needed for the ability of agents to exchange messages.

ITS comprises software, database and access to the computer system to manage the data it contains. The software part communicates with CAD/CAM for obtaining data from the system (see Fig. 3.) to perform data retrieval and further transmission to the database.

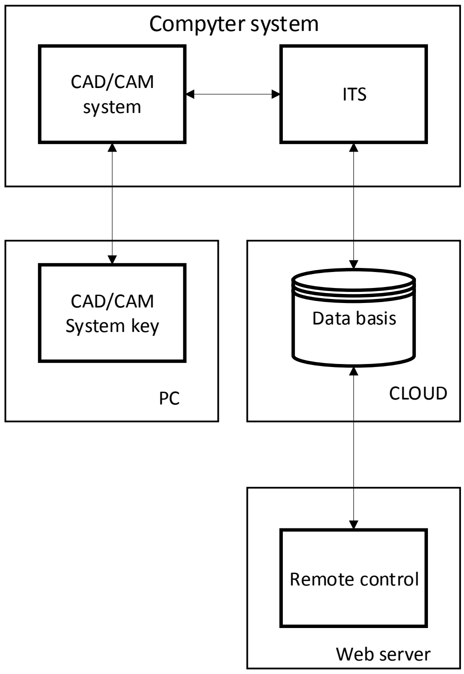


**Fig. 3.** The scheme of ITS performance.

ITS does not interfere with CAD/CAM at the system work, but, by using screen reading and intellectual agents that transfer data to each other, it carries out recording of user (trainee) activities and assess the tasks performed by sending these data to the database. ITS also lists the performance tasks carried out by the expert in order to maintain a sample of the database with which the agent compares the user's performance. The administrator is accessing the database through the Web to make adjustments to it, learn about the system, its usage, and update installation.

### 3.2 ITS usage

As the user enters the ITS, they are registered in the system. Features available to the expert are adding of new tasks, CAD/CAM tracking window (transparent, such as not interfering with CAD/CAM in use) adaptation to ITS, and the addition of CAD/CAM system tools and function keys to ITS. The trainee receives a work task, can move CAD/CAM system tools and function keys in a desired layout (if such an option in integrated into the CAD/CAM system), and activates the work test (activity tracking and analysis) that can be suspended if the trainee decides not to continue or at the end of the work when the task is executed.

ITS performs the following activities (see Fig. 4.):

1. At the start of training, the trainee receives a test task for the examination of the knowledge and skills acquired under a respective topic.

2. The trainee performs a task for training in the selected CAD/CAM system.

3. ITS conducts a knowledge assessment comparing the performance of the trainee with the data provided by the expert.

4. The trainee receives the result (feedback) when the system agents have extracted information about the adequacy and regularity of the performance of the trainee.

5. If work is done at an inadequate level, the trainee tasks concerning a respective topic are being offered to the trainee (the system determines the direct shortcomings and knowledge gaps identified and offers simple tasks for knowledge and skills acquisition concerning specific CAD/CAM system functions).

6. If work is done in accordance with the requirements, the assessment and transition leads to the end of the training.

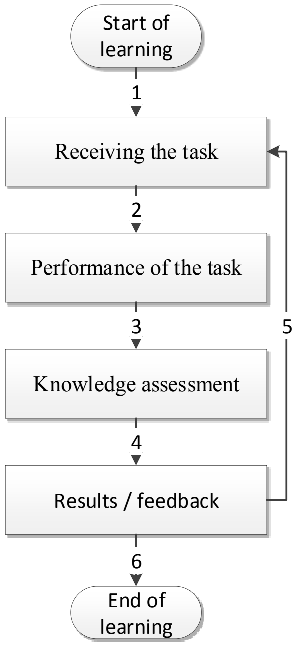


**Fig. 4.** Sequence of ITS workflow.

Restrictions on ITS development are linked to the development of CAD/CAM systems. The ITS is a multi-agent system consisting of five software agents that transfer data to each other and two individuals: an expert and a trainee who communicates with an interface agent. Agents involved: the following agent, the expert agent, the task agent and the evaluation agent, which all carry out tracking of the activities of the trainee, integration of the tasks assigned by the expert in the database and the support the award agent in the assignment process, while the evaluation agent evaluates the tasks performed by the trainee according to the information obtained from other agents.

In order to implement the main objective of ITS of verifying and evaluating trainee knowledge in CAD/CAM system use, it is necessary to develop test tasks integrated into the ITS and used according to the training plan and the skills to be tested.

Figure 5. demonstrates the process of assessing the performance of tasks, which shows that if the trainee chooses to continue, it can acquire additional tasks. If the trainee is scheduled to perform several test tasks during a single working session, then, alongside with the additional or recommended tasks, they are prompted to execute the scheduled task.

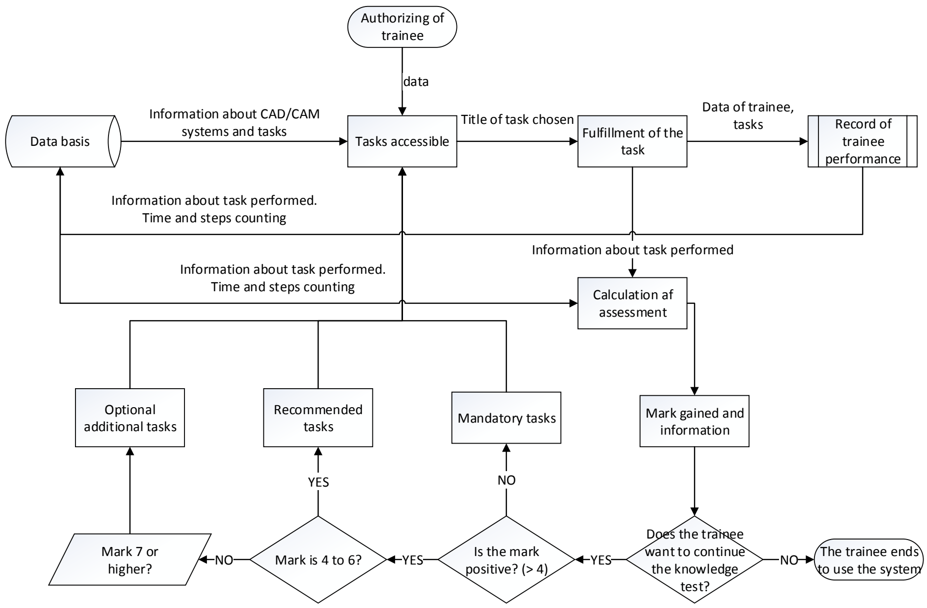


**Fig. 5.** The process of task evaluation.

When starting the system, the trainee must first register, then select the task to be performed. The system then offers to launch the task. Similarly as during the expert activities, all functions used are listed, fixed is time, quantity and frequency of their application. In order to perform the task, an image with the result is available to the trainee, which demonstrates how the drawing should look like, including its lines, breakdowns, construction lines, and dimensions. If the trainee submits a work they have not completed, the system provides feedback by declaring that the task is not fulfilled and is not valid for evaluation.

Each drawing can be created by using different sets of graphical items, while those items that are needlessly created are allowed to be deleted by the system, which is considered to be a drawback in user/trainee activities (unless deleting is an inevitable operation required to reset a separated line phase). Recording of such activities, identifying and analyzing of their time-intensity, enable to achieve better training results.

For instance, if one single command is available for a drawing of a particular object, but the trainee uses several lines to create one, it is considered as a drawback and time delay in the drawer's work  (a rectangular drawing command is present in almost all design systems, but sometimes users manage not to use it until they are completely familiar with the system). Such user-faulted and/or labor-intensive decisions cannot be analyzed by the teacher unless they are observing the entire duration of the task of the trainee and recording any movement of them. Monitoring of the performance of the work can be carried out through IT support in the training process by implementing it in the form of ITS. Agents' activities and cooperation allow not only to accumulate knowledge of the user activities in the system, but also to give a feedback to the trainee with by providing an analysis of the activities.

The developed ITS prototype CAD/CAM system is evaluated by the agent that determines its completion, completeness and the possibility of qualifying for a mark by submitting the task. If the task is not complete, the trainee receives a statement that the work cannot be evaluated. The agent is responsible for work evaluation, enumeration of functions, calculation of the trainee’s mark, provision of feedback. The expert receives information about all the actions performed, the list of functions, pause and time distribution, the calculated mark. The trainee receives a mark and information about success and recommended activities.

## 4 Conclusions and discussion

CAD/CAM learning is very complicated: the range of skills includes good knowledge of the production sphere, 2D and 3D design, mathematical and IT skills, object and product visualization, drawing skills and other complex knowledge. In the learning process there still is unknown interaction between the student and the content of learning. By studying how knowledge is acquired and what kind of learning support contributes to learner education and motivation, it is possible to improve computer-aided design training.

The system established enables to provide solutions for design system assessment problems: the expert is informed on the activities of the trainee during performance of the tasks, the process of execution of the task. The expert may, through information collected by the system agents, analyze the effectiveness of the work carried out, the compliance of the tools/ functions used with the working task, consistency of the process and effectiveness of the activities. Such an intellectual learning system makes it possible to solve problems related to the assessment of work of the trainee, and it is possible to analyze the activities of the trainee and to give feedback on their knowledge and skills.

The established ITS allows to assess the knowledge of trainees in CAD/CAM system use systematically, i.e., checking and analyzing each step and time of execution of the finalized task. Such a system (ITS) also allows for the analysis of the quality of the tasks created and the adequacy of the necessary knowledge. If a teacher integrates self-assessment tasks into the system, the established ITS also allows to carry out an individual self-assessment of one’s knowledge, thus taking a picture of the gained information. This allows the trainee, regardless of the teacher, to control the level of knowledge and to learn the delay in a timely manner if there is a lack of knowledge identified.

## Acknowledgement

Many special thanks to all students contributed in approbation of the system.

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